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DEVELOPMENT AND TESTING OF THE HYDRO-ADIABATIC DETONATOR

31 JULY 1970

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NAVAL WEAPONS STATION, YORKTOWN, VIRGINIA 23491

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by

E. Yancey McGann

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Engineering and Special Projects Division
Explosives Engineering and Research Department

NAVAL WEAPONS STATION
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ABSTRACT: This report describes the work conducted to develop a simple explosive device to replace present complicated arming and firing mechanisms used in underwater sound signals. This device contains no primary explosive and represents a significant improvement in the design and safety of explosive devices. Potential applications are not limited to underwater sound signals.

Submitted by

E. Yancey McGann, Head
Engineering and Special Projects Division

DEVELOPMENT AND TESTING OF THE HYDRO-ADIABATIC DETONATOR

1. The investigation herein described is a summary of work conducted by the Explosives Engineering and Research Department of the Naval Weapons Station, Yorktown, Virginia to evaluate the feasibility of initiating a secondary explosive by the adiabatic compression of air. This is a final progress report of work performed under the Naval Underwater Weapons Research and Engineering Station, Newport, Rhode Island, Project Order No. 9-0251.

2. The findings in this report are not to be construed as an official Department of the Navy position. While the data is believed to be accurate, it is subject to change and is therefore released as information at the working level.

W. J. MADDOCKS
Captain, USN
Commanding Officer

U. Cormier
U. CORMIER
By direction

CONTENTS

ACKNOWLEDGEMENTS

The concept for this device and many of the ideas were contributed by Messrs. Carl A. Axelson and John R. Hinves, Naval Underwater Weapons Research and Engineering Station, Newport, Rhode Island.

The ideas contributed by Mr. John H. Smith, Naval Weapons Station, Yorktown, Virginia during the development of this hydro-adiabatic detonator were instrumental in translating it from a laboratory curiosity to an effective firing detonator.

DEVELOPMENT AND TESTING OF THE HYDRO-ADIABATIC DETONATOR

I. GENERAL

The principles involved in the adiabatic compression or expansion of a gas are well known as this phenomenon is used as the basis for design of many types of equipment to do useful work.

The phenomenon of adiabatic compression of air trapped in voids found in the explosive loads of ordnance material has been studied (1) and modern loading processes are designed to eliminate such voids, as these are potential sources of accidental explosive initiation.

During mid-1967, the Naval Underwater Weapons Research and Engineering Station, Newport, Rhode Island, undertook a task to explore the possibility of utilizing the principle of adiabatic compression of air to initiate a secondary explosive for possible application to underwater explosive devices. The Explosives Engineering and Research Department, Naval Weapons Station, Yorktown, Virginia, has worked with NUWR&ES Newport in this effort and the results herein reflect the ideas jointly contributed. NUWR&ES Newport published an interim report (2) on the progress of the work in January 1968.

II. OBJECTIVES

The objective of this task was to design a simple, reliable device to replace present complicated arming and firing mechanisms. Such a device must produce high order detonation of a secondary explosive (in this instance CH-6, which is 97.5% RDX/.5% Polyisobutylene/ 1.5% Calcium Stearate/.5% Graphite) without using primary explosives such as lead styphnate, lead azide, etc., in order to meet explosives safety design criteria. The sensitive primary explosives have always been a problem in the design of ordnance material because of the somewhat unpredictable nature of the material. As a result, the military services have established rather stringent safety precautions that must be followed in the design of an explosive train. The guide for Navy designs is MIL-STD-1316, Fuzes, Navy, Design Safety Criteria for. In general, MIL-STD-1316 requires that no explosive more sensitive than Tetryl shall be used in a position such that it can communicate detonation to the main charge.

Because of this requirement, designs of the various explosive devices are somewhat complex in order to meet a standard of safety that will eliminate accidental initiation of explosive devices.

In this report, the discussion of design features of explosive trains are made with underwater sound signals in mind. It must be emphasized however that the device described herein can be used in many other applications. In general, the existing designs of explosive trains contain the following elements: a firing pin, a detonator, an explosive lead, a booster, and a main explosive charge. Figure 1 is the standard Fleet issue underwater sound signal. Detonation is transferred from the smallest explosive element (the detonator) to other explosive elements that increase in size and, therefore, output. These designs have evolved as the result of many years of experimenting and testing.

III. IMPLICATIONS

The development of an explosive device that eliminates primary explosives from the firing train represents an extremely significant advance in the field of explosive devices design. The hydro-adiabatic detonator described herein will eliminate the necessity for any moving parts or primary explosive in firing trains with a resultant increase in reliability and decrease in cost. Figure 2 is a proposed application for the device.

IV. PRINCIPLE INVOLVED

The design of the device described herein is based on the use of the available energy of sea water at deep depths. The energy of the sea water is used to suddenly compress air to produce the heat and pressure required to initiate an explosive column. To date, this device has been tested only at depths of 1,000 feet and greater. It is quite possible that the device will work at shallower depths or that the design can be slightly changed to produce functioning at shallow depths.

V. DETAIL TESTING

A number of different designs and variations were tested but only the most significant ones will be discussed. These will be discussed in the order that they evolved. In all of the work described, the explosive load is CH-6.

The first design tested is shown in Figure 3. Water under a pressure head is held back by a shear disc assembly. Operation of the shear disc allows the water to rush into the tapered cavity where the converging wall directs it to a soft aluminum cap that retains a hemispherical rubber plug in place. The cap and rubber plug are crushed downwards causing the air entrapped under the rubber plug to be compressed into a needle shaped cavity formed in the CH-6 explosive load. This raises the temperature of the air in contact with the explosive to the ignition point of the explosive which then begins to burn. As the explosive burns it produces more heat and pressure, and hopefully, the transition from burning to detonation will take place. Figure 3 shows cut sections of three units tested (Nos. 2, 4, and 5) and one before testing (not numbered

and minus explosive load). The body section containing the explosive was fabricated from aluminum. In the photograph, the shear disc assembly can be seen as the washer shaped assembly at the right end of the tapered cavity. The dome shaped aluminum cap and rubber plug are seen at the left end of the tapered cavity. Seventeen of these devices were tested. Although high order detonation of the CH-6 was not attained, the transition from burning to low order detonation at the point of ignition was made in all units tested. Almost all units exhibited a bell shaped deformation seen at the point where ignition takes place.

Since this device apparently could not be made to detonate high order, NUWR&ES Newport directed considerable thought to the design and, eventually, a new concept was proposed, Figure 4. The proposed new device eliminated the aluminum cap and rubber plug and represented a radical departure from the first design. In the new design, there is no interface (except air) between the water and the explosive after operation of the shear disc. This concept, in effect, defies the old axiom to "keep your powder dry." Water is held back by a shear disc assembly as in the first design. Under the shear disc, the walls of the device taper uniformly inward to a sharp point formed in the explosive. Operation of the shear disc permits water to rush down the tapered hole compressing the air ahead of it into the small needle point shaped cavity in the explosive while raising the temperature to the ignition point of the explosive. The explosive is ignited and once again heat and pressure build up to make the transition from burning to detonation. Between December 1967 and May 1968, 20 devices, including variations of the basic device, were tested. In all instances except one, only low order detonation was achieved. One device, which was a variation of the basic hardware, was made to detonate high order on 6 May 1968. A cross section of this device is shown in Figure 5. The idea for this variation came from a report published by the Armour Research Foundation of Illinois Institute of Technology (3). Part of the work reported involved the problem of forcing a column of explosive to make the transition from burning to detonation. This was accomplished by introducing an air gap and metal bulkhead in the middle of the explosive column. Aluminum was selected as the best material to use in the bulkhead. The principle involved is to hurl high velocity particles of molten metal across an air gap into a column of explosive in order to initiate high order detonation. The first, or initiator, column provides the heat and pressure necessary to melt or vaporize the aluminum and propel the resulting particles across the air gap.

During June 1969, a series of tests to explore the gap principle were conducted. The external appearance of the hardware used was slightly different from that used in the high order firing of May 1968. However, the internal configuration was essentially the same. At this point, a critical examination of the hardware was begun. From the beginning, all hardware, except that used in the first design, had been fabricated from commercial brass. After each firing, the hardware was carefully

examined and in each instance, enlargement of the hole containing the explosive was noted. This led to a conclusion that the brass was probably not giving the confinement necessary to assist in making the transition from burning to detonation. As a result, two sets of hardware were fabricated from stainless steel. The hardware was assembled as shown in Figure 5. Both units detonated high order. Figure 6 is a photograph of the hardware before and after firing. It was evident, therefore, that the added confinement (steel) was necessary.

The success of the firings using stainless steel parts led to a decision to proceed with a hardware configuration that would be more adaptable to general use. Accordingly, Figure 7 shows the current design hardware being tested. Basically, the device consists of a shear disc, an explosive column of CH-6 with an aluminum disc at one end, an air gap and a pickup cup loaded with CH-6. Heat and pressure builds up in the column of CH-6 to melt the aluminum disc and hurl the particles into the pickup cup.

In the first device tested, the column of CH-6 was 1-1/2 inches long. A standard 5/8-inch mild steel plate was butted against the bottom of the pickup cup and the device was fired at a simulated depth of 2,000 feet. Figure 8 is a sketch of the test setup. Two devices were fired and both fired high order. An indentation of .043 inch was measured in the steel plate. Two more devices were made with a 1-inch long CH-6 column. These were tested in the same manner as the 1-1/2 inch long explosive column devices. Both units fired high order and an indentation of .037 inch was made in the steel witness plate. Two more tests were conducted using 1/2-inch and 3/4-inch long explosive columns. Indentations of .006 inch and .008 inch respectively were noted. Figure 9 is a photograph of both the expended and the unexpended hardware. Based on these tests it was decided to use a 1-inch long CH-6 column length in future units.

Further testing was conducted on 26 January 1970 using 1-pound charges of flexible explosive manufactured in accordance with MIL-E-46676. Two devices, one having a 1-inch column of CH-6 and one having a 1-1/2-inch column of CH-6 were butted against 1-pound explosive charges. The assembly was then installed in a water filled pipe and the pressure raised with a nitrogen cylinder. Shear discs set for 2,000 feet were installed in the devices. Both devices fired high order. Figure 10 is a schematic diagram of the test firing arrangement.

VI. CONCLUSIONS

The hydro-adiabatic detonator described in this report has an excellent potential for simplifying existing arming and firing mechanisms used in underwater explosive devices. It has the advantages of eliminating primary explosives with all of the accompanying hazards. Because of its simplicity, reliability will be greatly improved and an almost indefinite magazine storage life envisioned. Because of the reduction in the number and complexity of parts, manufacturing costs

will be considerably less and inspection of parts will be much easier and consequently less expensive. Although extensive testing has not been undertaken, the safety of this device should make it quite attractive. Since it uses a standard service accepted explosive suitable for use in line with the main charge, all safety tests of the explosive itself have been completed. Since the device requires a slug of high pressure fluid such as water to compress the air in the tapered cavity, it should be insensitive to accidental initiation from normal environmental stimuli. As a result, testing of this device to ensure safety in handling and use should be relatively uncomplicated. Environmental and safety testing will be conducted in the near future.

VII. APPLICATION

Two possible applications of this device are shown in Figures 2 and 11. In Figure 2, the initiator is shown with a 1/4-pound charge of flexible explosive packaged in an aluminum tube. Figure 11 shows a larger device having a 1.9-pound charge of flexible explosive. The hardware shown in Figure 11 is a modification of the existing hardware set used in the Mk 59 Mod 5 Search and Rescue Signal. A comparison of this design with the design of a standard signal (Figure 1) will demonstrate the simplicity of the hydro-adiabatic detonator and should lead to serious consideration of the potential application.

VIII. REFERENCES

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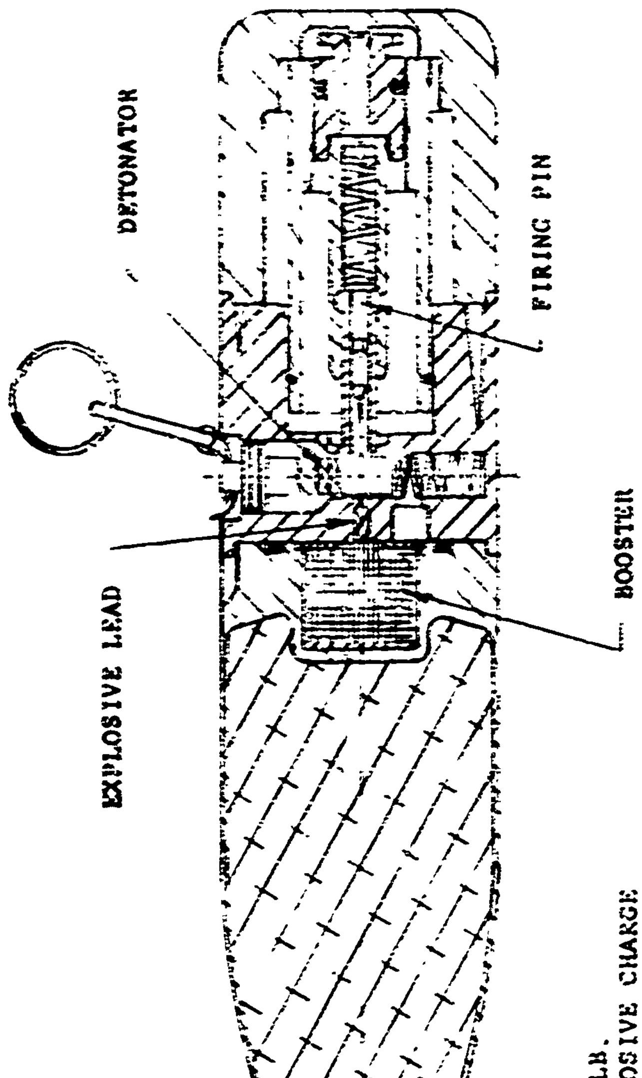
(2) Axelson, C. A., NUWS CR No. 2, Interim Report, Initiation of a Secondary Explosive by Sea Water, Naval Underwater Weapons Research and Engineering Station, Newport, Rhode Island, Jan 1968

(3) Cooper, P. W., ARF Project D178, Final Report summarizing Phase I: Low Firing Energy Detonator Containing No Primary Explosives; Phase II: Explosive Recording Device, Period covered 4 Sep 1958 to 15 Jun 1960, Armour Research Foundation of Illinois Institute of Technology, 15 Jun 1960



SIGNAL, UNDERWATER SOUND, MK 61 MOD 0

FIGURE 1

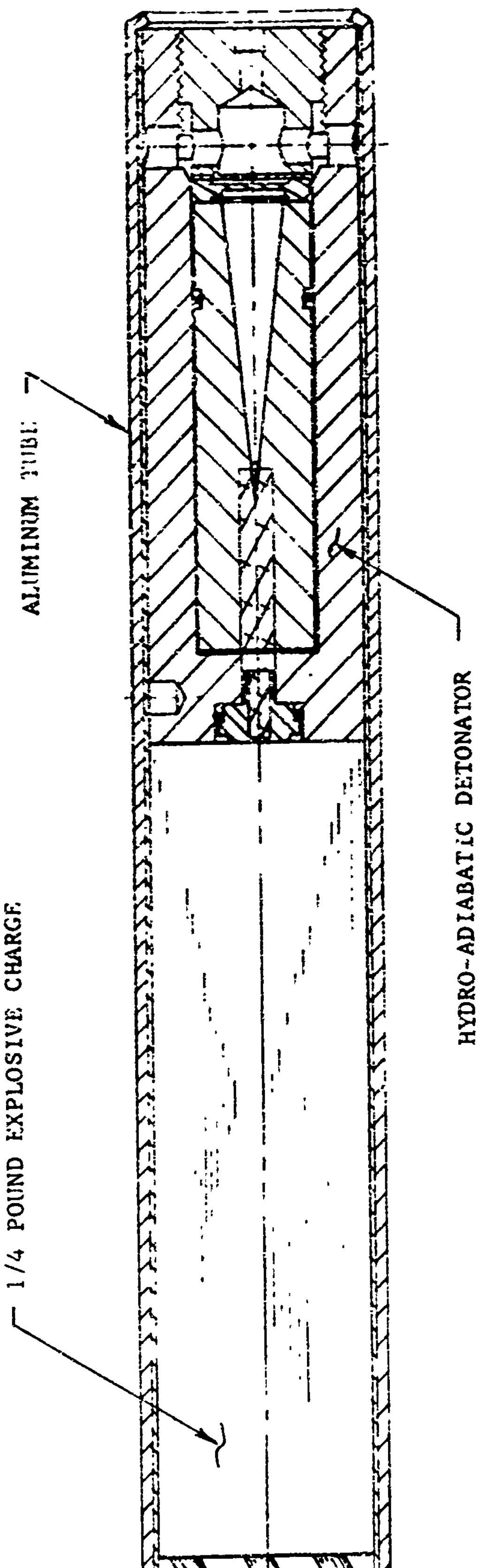


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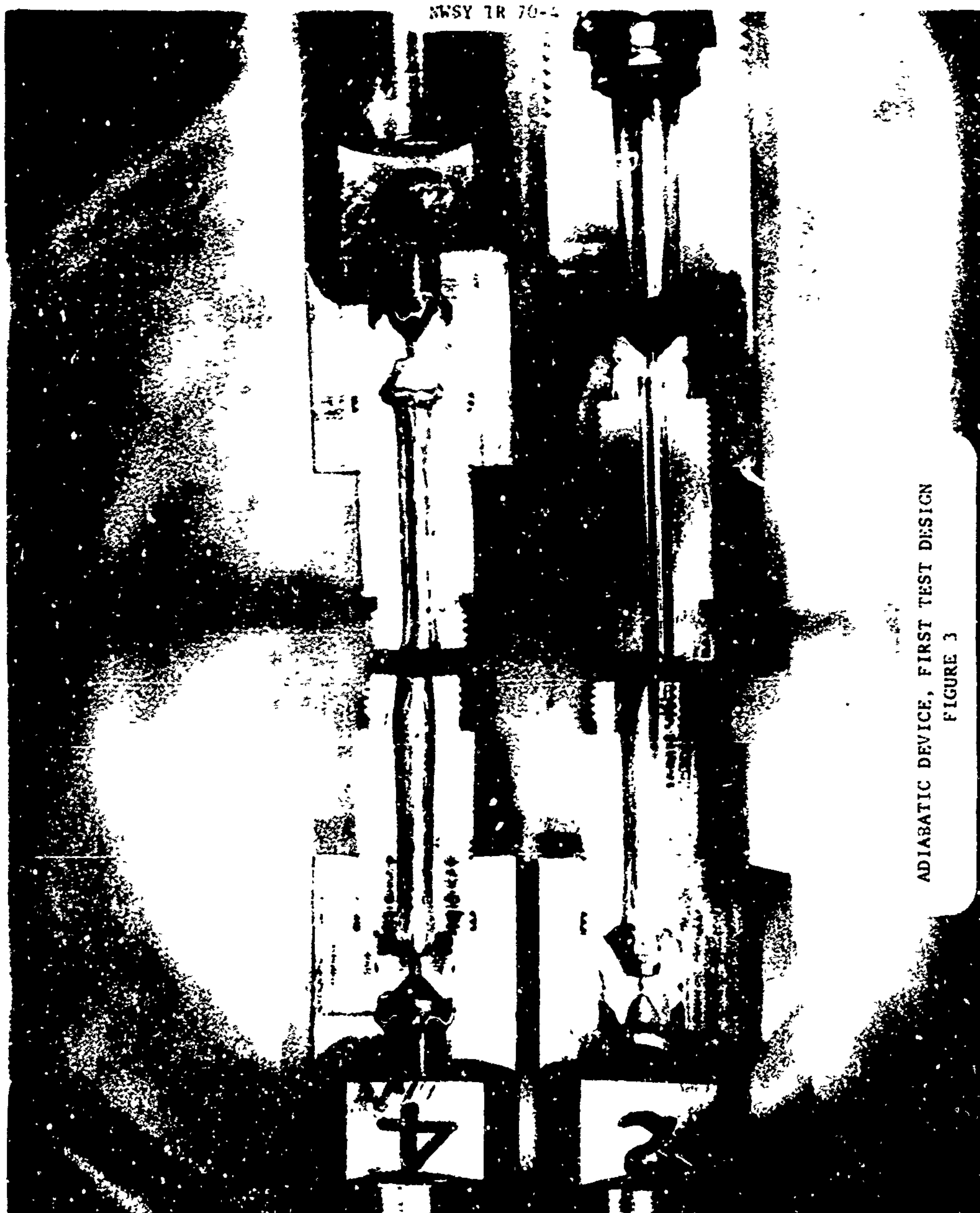
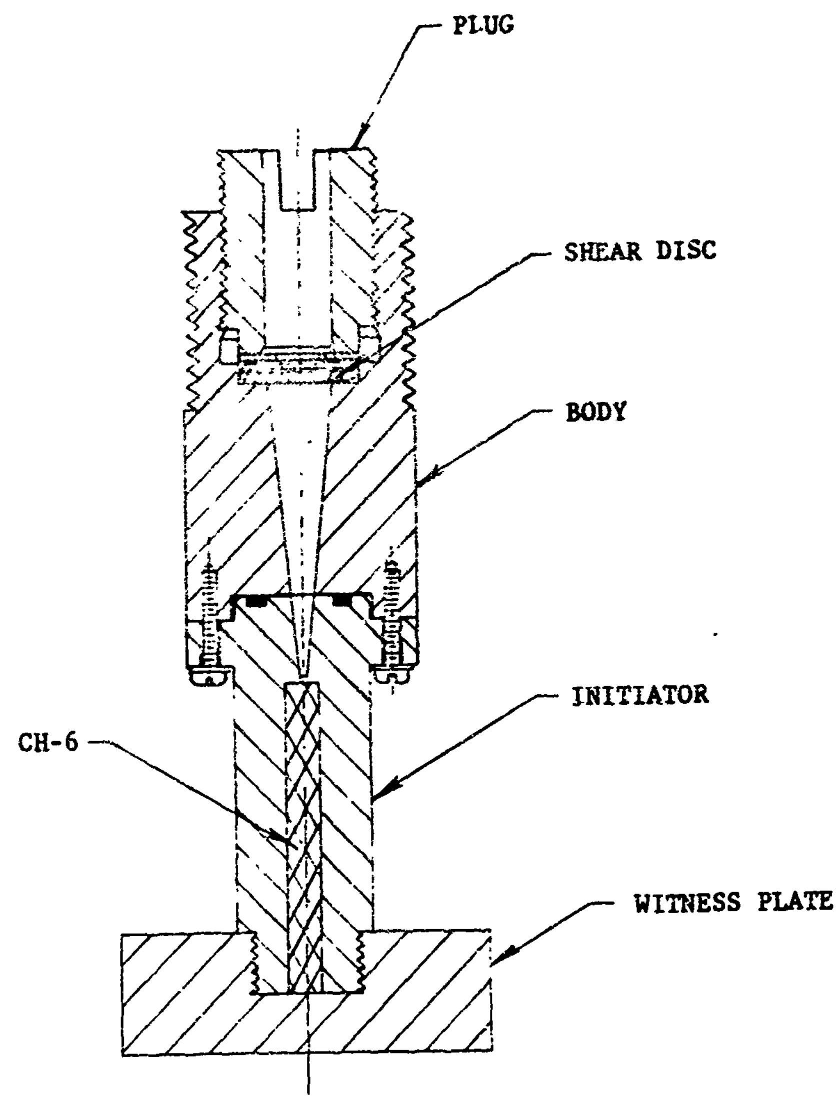
FIGURE 2

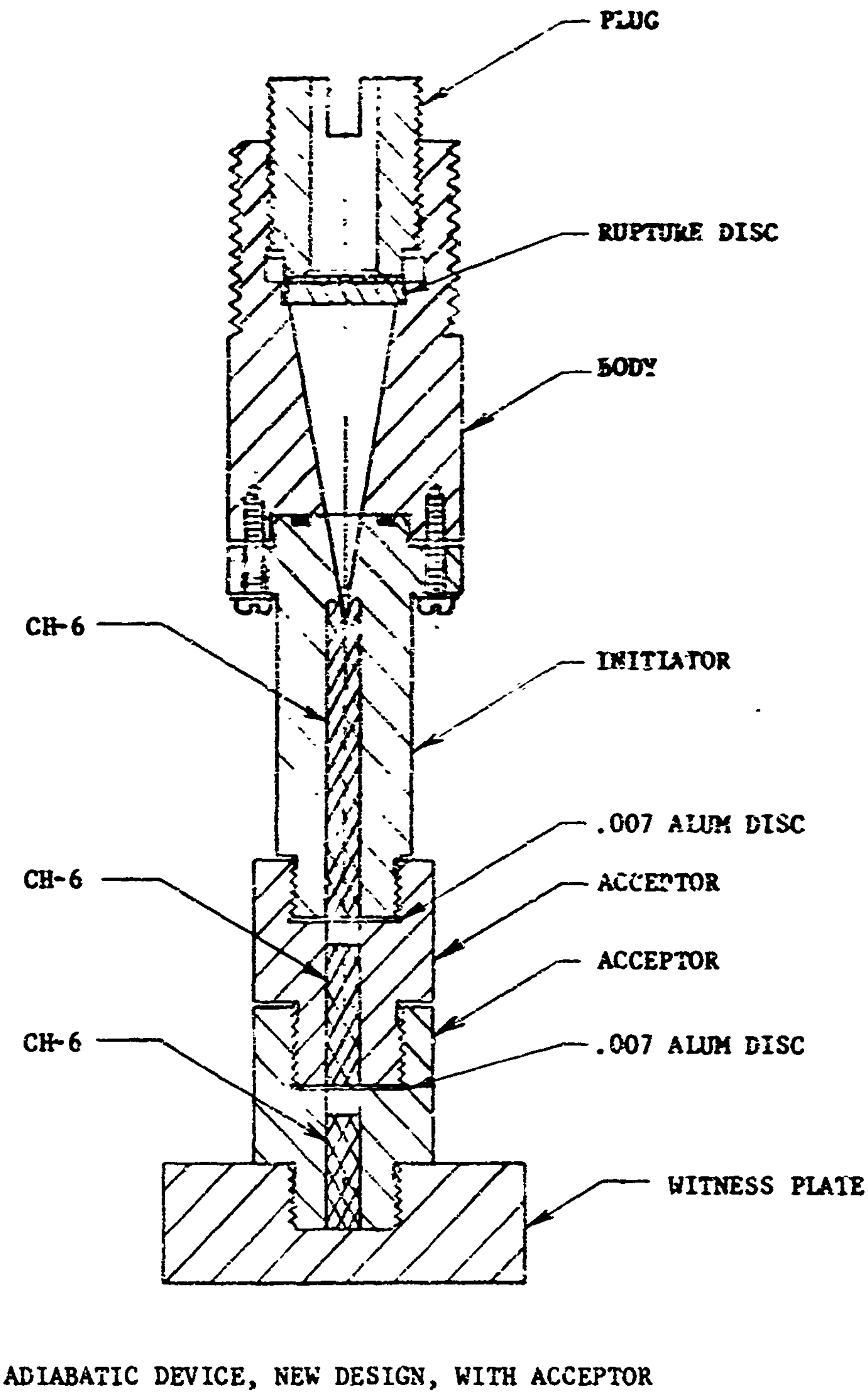


ADIABATIC DEVICE, FIRST TEST DESIGN
FIGURE 3



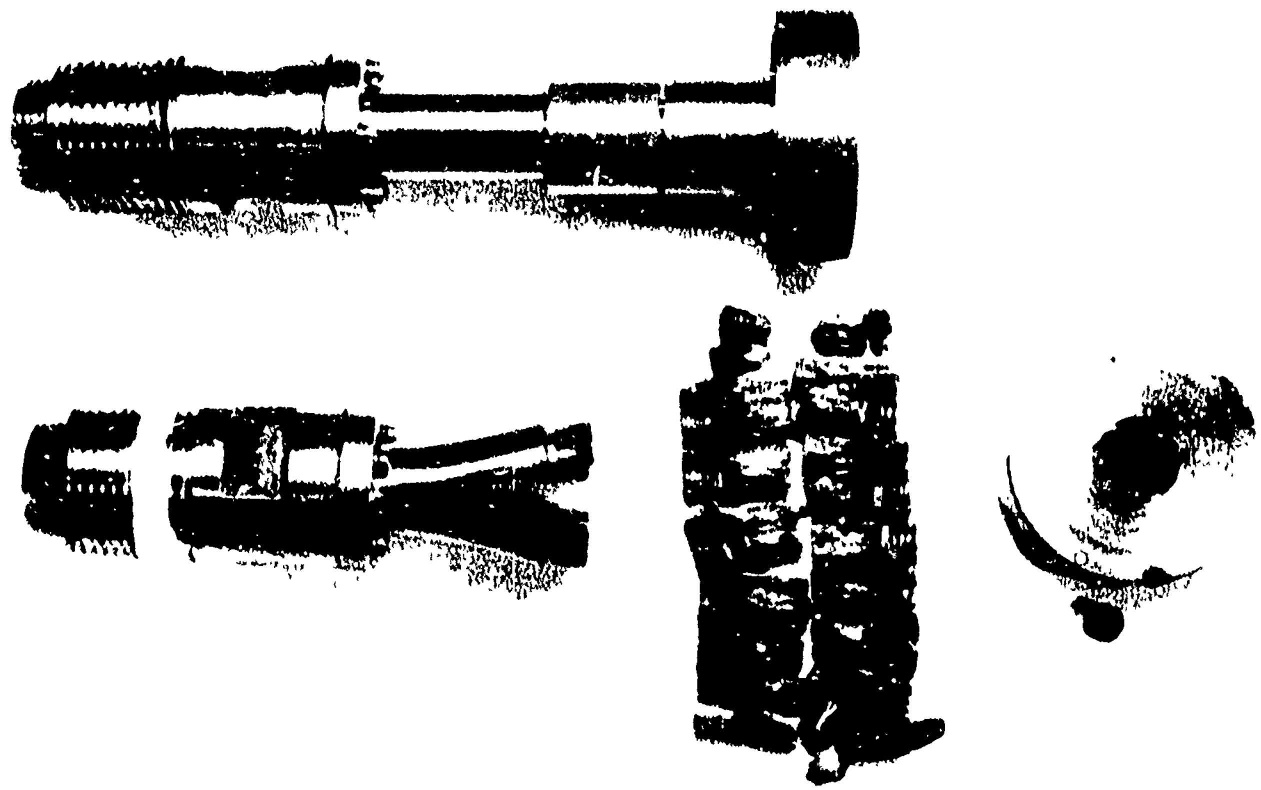
ADIABATIC DEVICE, NEW DESIGN, WITHOUT ACCEPTOR

FIGURE 4

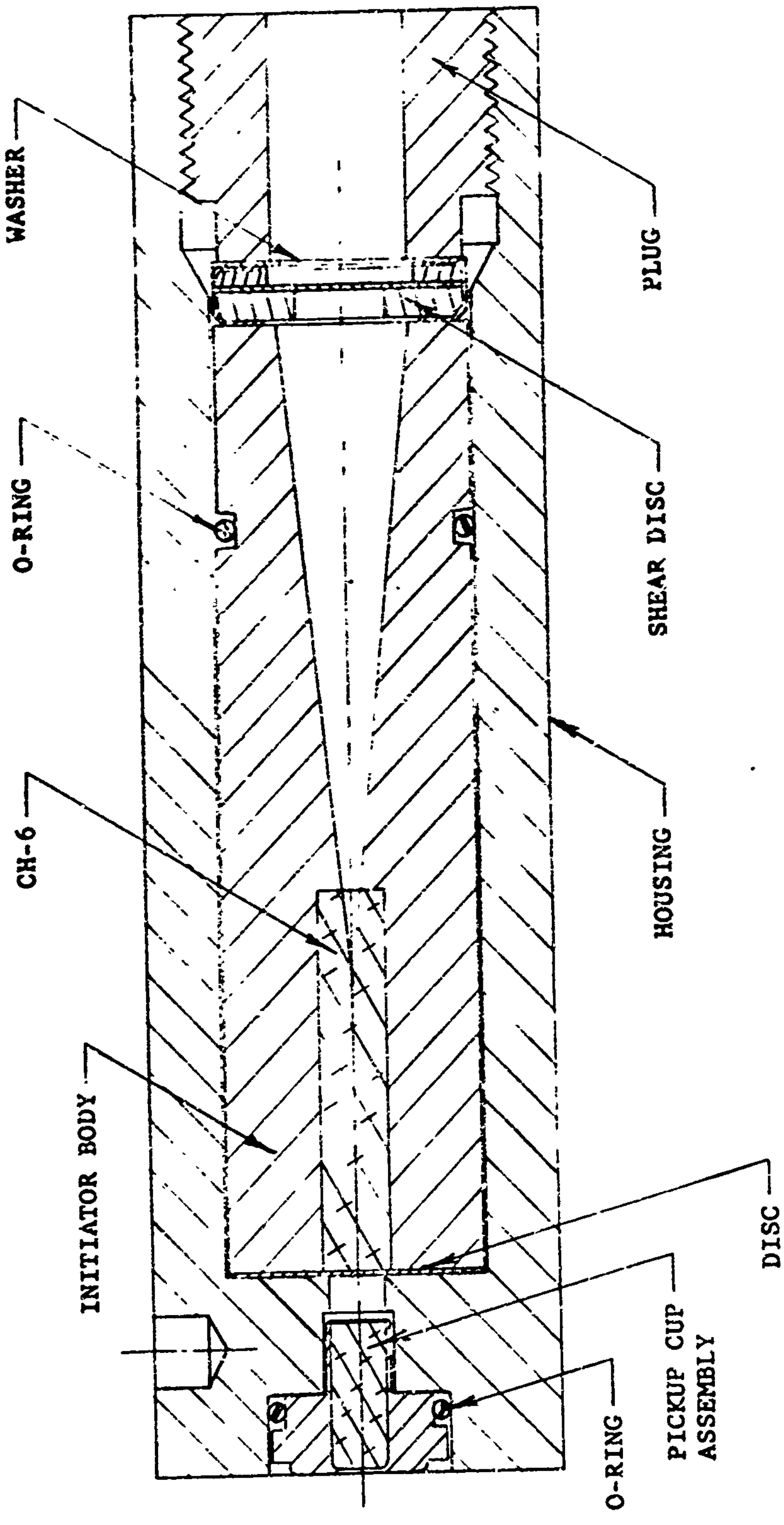


ADIABATIC DEVICE, NEW DESIGN, WITH ACCEPTOR

FIGURE 5

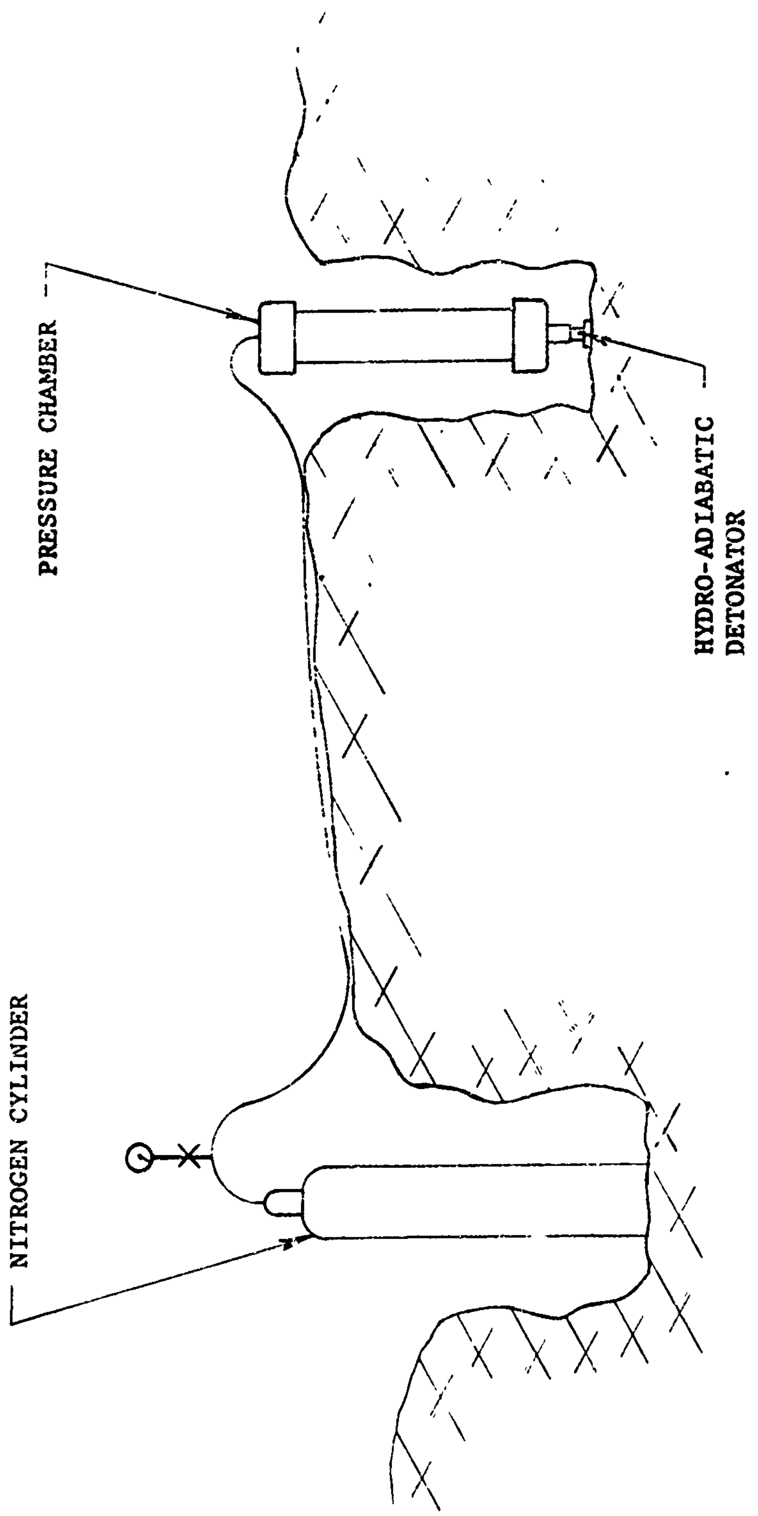


ADIABATIC DEVICE, NEW DESIGN,
BEFORE AND AFTER TEST FIRING
FIGURE 6



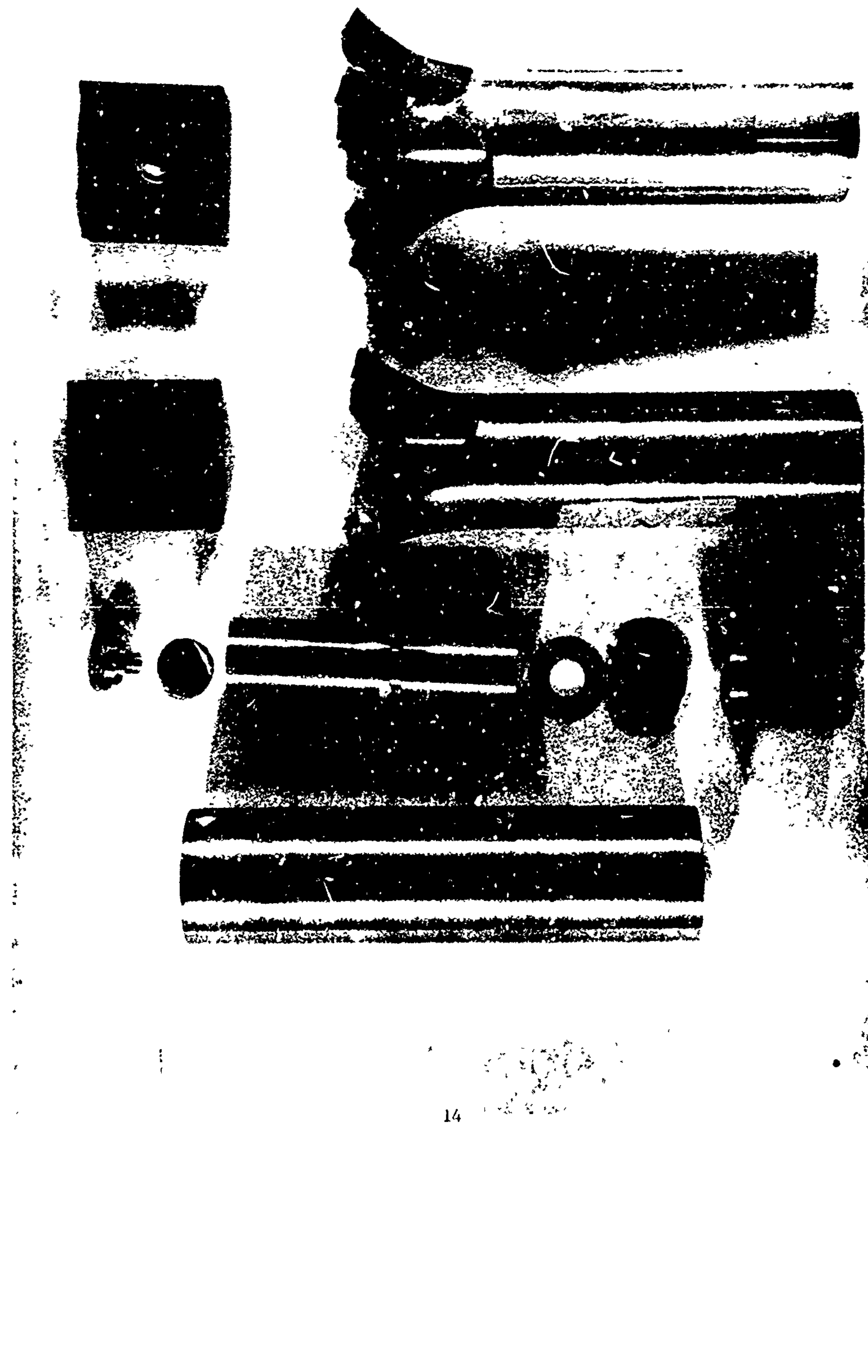
ADIABATIC DEVICE CURRENTLY UNDER TEST

FIGURE 7

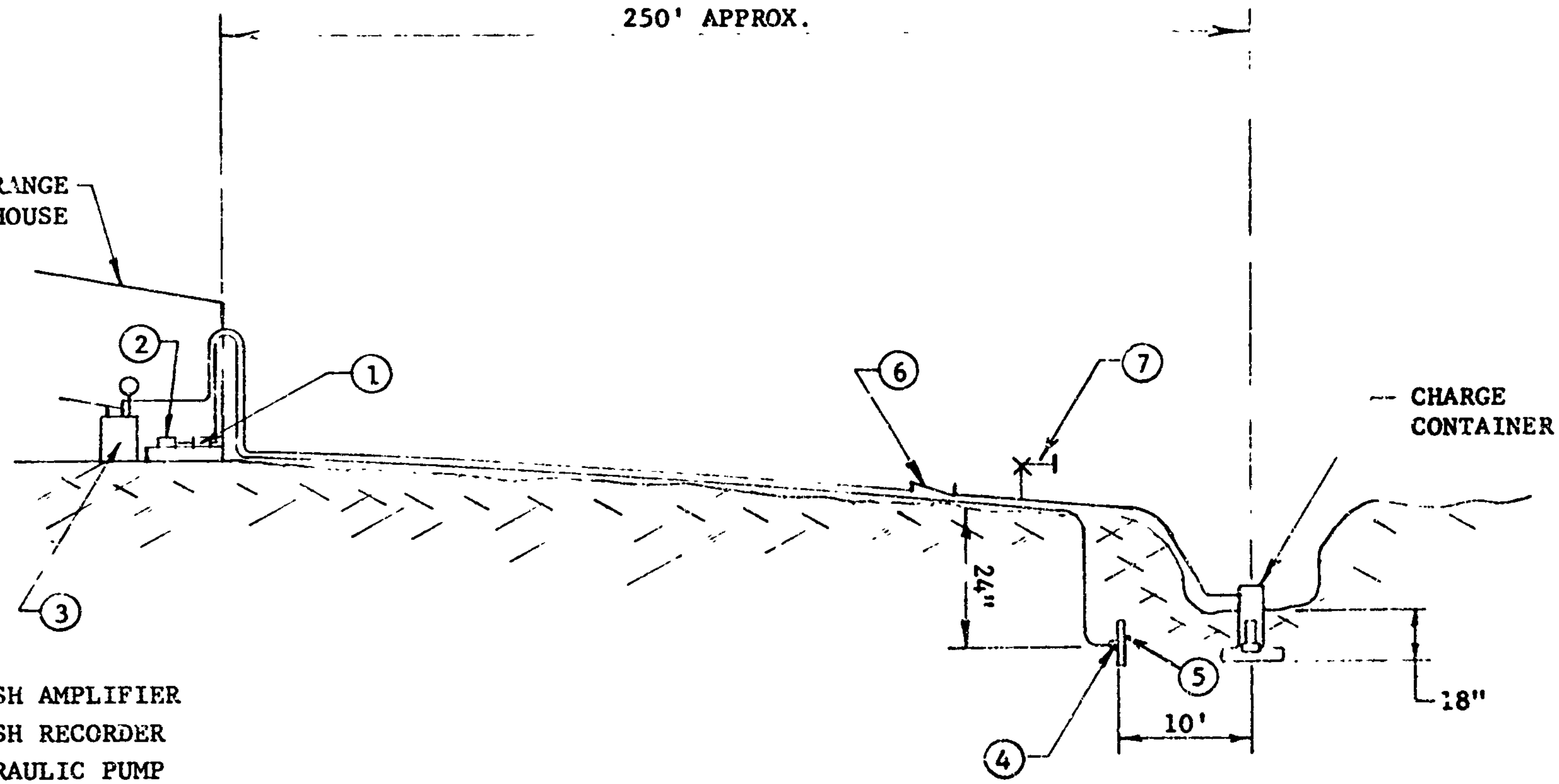


ADIABATIC DEVICE FIRING TEST SETUP USING WITNESS PLATES

FIGURE 8



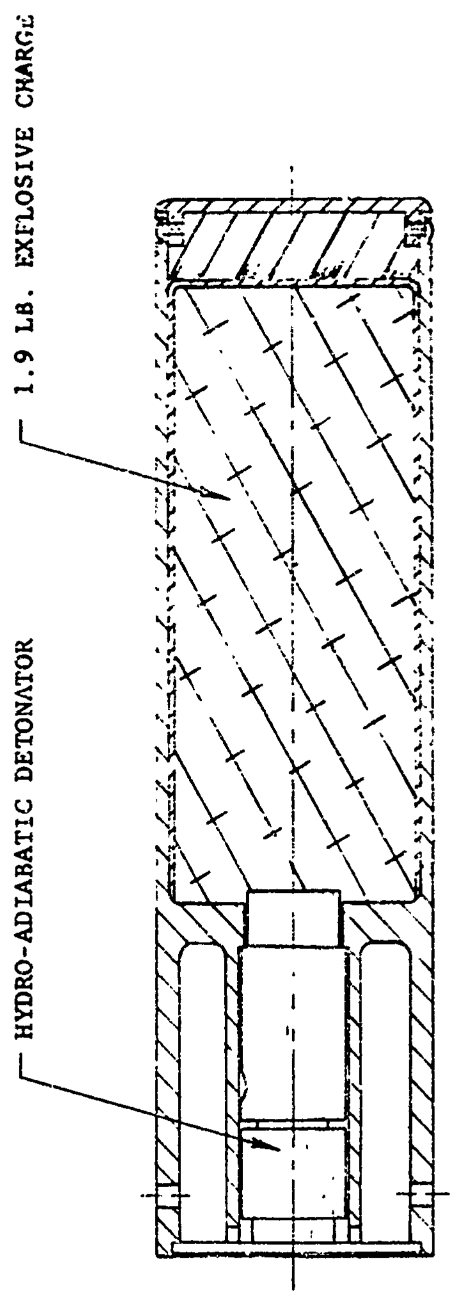
ADIABATIC DEVICE
BEFORE AND AFTER TEST FIRING
FIGURE 9



(1) BRUSH AMPLIFIER
(2) BRUSH RECORDER
(3) HYDRAULIC PUMP
(4) MB VIBRATION PICKUP
(5) 5" x 8-1/2" x 1/4" THK ALUMINUM PLATE
(6) CHECK VALVE
(7) BALL VALVE

ADIABATIC DEVICE FIRING TEST SETUP USING 1-POUND CHARGES

FIGURE 10



SIGNAL, UNDERWATER SOUND, EX 59 MOD 6

FIGURE 11

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Development and Testing of the Hydro-Adiabatic Detonator

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Naval Weapons Station, Yorktown, Technical Report

5. AUTHOR(S) (Last name, first name, initial)

McGann, E. Yancey

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
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13. ABSTRACT

This report describes the work conducted to develop a simple explosive device to replace present complicated arming and firing mechanisms used in underwater sound signals. This device contains no primary explosive and represents a significant improvement in the design and safety of explosive devices. Potential applications are not limited to underwater sound signals.

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Detonator, hydro-adiabatic						
Initiator, explosive, simplified						

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